Final Total Maximum Daily Load for Pathogens, Cane Creek Watershed, Kentucky River Basin, Kentucky

Kentucky Division of Water
Environmental and Public Protection Cabinet

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Kentucky Department for Environmental Protection
Division of Water

This report is approved for release

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Date

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TMDL Synopsis

1. 303(d) Listed Waterbody Information:

State: Kentucky
Major River Basin: Kentucky River
8-Digit HUC: 05100204
Counties: Powell, Menifee

Waterbody (GNIS#)	River Mile	Listing Year	Use Impairment(s)	Support Status	Priority	Pollutant
Cane Creek of Red River (511187)	0.0 to 3.1	2002	Primary Contact Recreation (Swimming)	Non-Support	First Priority	Pathogens

In addition, the following stream segments were assessed as impaired using data collected for this TMDL.

Waterbody (GNIS#)	River Mile	Listing Year	Use Impairment(s)	Support Status	Priority**	Pollutant
Lower Cane Creek of Cane Creek (513680)	0.0 to 4.1	*	Primary Contact Recreation (Swimming)	Non-Support	First Priority	Pathogens
Middle Fork of Right Fork Cane Creek (513936)	0.0 to 2.8	*	Primary Contact Recreation (Swimming)	Non-Support	First Priority	Pathogens
Right Fork Cane Creek of Cane Creek (514935)	2.2 to 5.2	*	Primary Contact Recreation (Swimming)	Partial Support	Second Priority	Pathogens

* These stream segments are newly assessed as impaired and the public notice requirement for listing these segments is addressed by the public participation requirement of the TMDL process. The listing year is therefore 2008, which is the year of the next Integrated Report to Congress on Water Quality in Kentucky. However, these segments will not appear in Category 5A (which are stream segments requiring TMDLs) in the 2008 report but in Category 4A (which are stream segments with approved TMDLs).

** Although these segments will not be listed in Category 5A of the 2008 303(d) report (which is Volume II of the Integrated Report), they meet the criteria for the priority assigned.

2. Pollutant Allocations:

Location		Existing Conditions		TMDL = WLA + LA + MOS				TMDL Target	Percent Reduction Needed to Achieve TMDL Target	
		Load, billion colonies/day			Final Allocation, billion colonies/day				Percent Reduction, billion colonies/day	
Station Name	Stream (River Miles)	Wasteload	Load	TMDL (WQC as a Load), billion colonies/day	WLA[1]	LA	MOS,[2] billion colonies/day	TMDL Target Load (WQC minus MOS), billion colonies/day	WLA	LA
5	Right Fork Cane Creek of Cane Creek (2.2 to 5.2)	0	50.31	10.06	0	9.06	1.00	9.06	0%	82.0%
4	Middle Fork of Right Fork Cane Creek (0.0 to 2.8)	0	68.69	9.51	0	8.56	0.95	8.56	0%	87.5%
3	Lower Cane Creek of Cane Creek (0.0 to 4.1)	0	65.79	5.64	0	5.08	0.57	5.07	0%	92.3%
1	Cane Creek of Red River (0.0 to 3.1)	0	39.24	4.22	0	3.80	0.42	3.80	0%	90.3%

[1]Any future permitted point source must meet permit limits based on the Water Quality Standards in 401 KAR 5:031, and must not cause or contribute to an existing impairment.
[2]An explicit MOS of 10% was used, along with an implicit MOS from using conservative methods to calculate existing conditions.

1.0 Introduction

Section 303(d) of the Clean Water Act requires each State to identify those waters within its boundaries for which required effluent limitations are not stringent enough to implement any water quality standard applicable to such waters. States must establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters.

Also, Section 303(d) requires each State to establish the Total Maximum Daily Load (TMDL) for the pollutants that cause the waterbody to fail to meet its designated uses. Such a load must be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

2.0 Problem Definition

3.1 miles of Cane Creek in Powell County, Kentucky, are listed on the 2006 303(d) List as being impaired for the Primary Contact Recreation (PCR) use (i.e., swimming) due to pathogens. The listed segment begins at the mouth of Cane Creek (i.e., River Mile, or RM, 0.0, where it discharges into the Red River) and ends at RM 3.1, see Figure 1.1 for a map of the watershed showing the impaired segment, and see Appendix C for a map showing local roads. Cane Creek was first listed on the 2002 303(d) List. The sources of the impairment are described as Livestock (Grazing or Feeding Operations). In the course of collecting data for this report, additional pathogen impairments were discovered in Lower Cane Creek of Cane Creek, Middle Fork of Right Fork Cane Creek and Right Fork Cane Creek of Cane Creek, see Section 5.0.

3.0 Physical Setting

3.1 General Information

Cane Creek comprises a Hydrologic Unit Code (HUC) 11, #05100204150, in the Kentucky River Basin, and its Geographic Names Information System (GNIS) number is 511187. As shown on Figure 3.1, Cane Creek separates at RM 3.1 into Lower Cane Creek (GNIS 513680) and Right Fork Cane Creek (GNIS 514935). Middle Fork of Right Fork Cane Creek (GNIS 513936) joins Right Fork Cane Creek at RM 2.2. See Table 3.1, below, for elevation, length, area and slope data for the major streams in the watershed. These values were obtained by comparing the National Hydrography Dataset (NHD) stream milepoints with elevations from the Digital Elevation Model within the Kentucky Environmental and Public Protection Cabinet's Geographical Information Systems (GIS) Singlezone Portal. Although the listed segment and the majority of the Cane Creek watershed are in Powell County, a small portion of Right Fork Cane Creek is located in Menifee County.

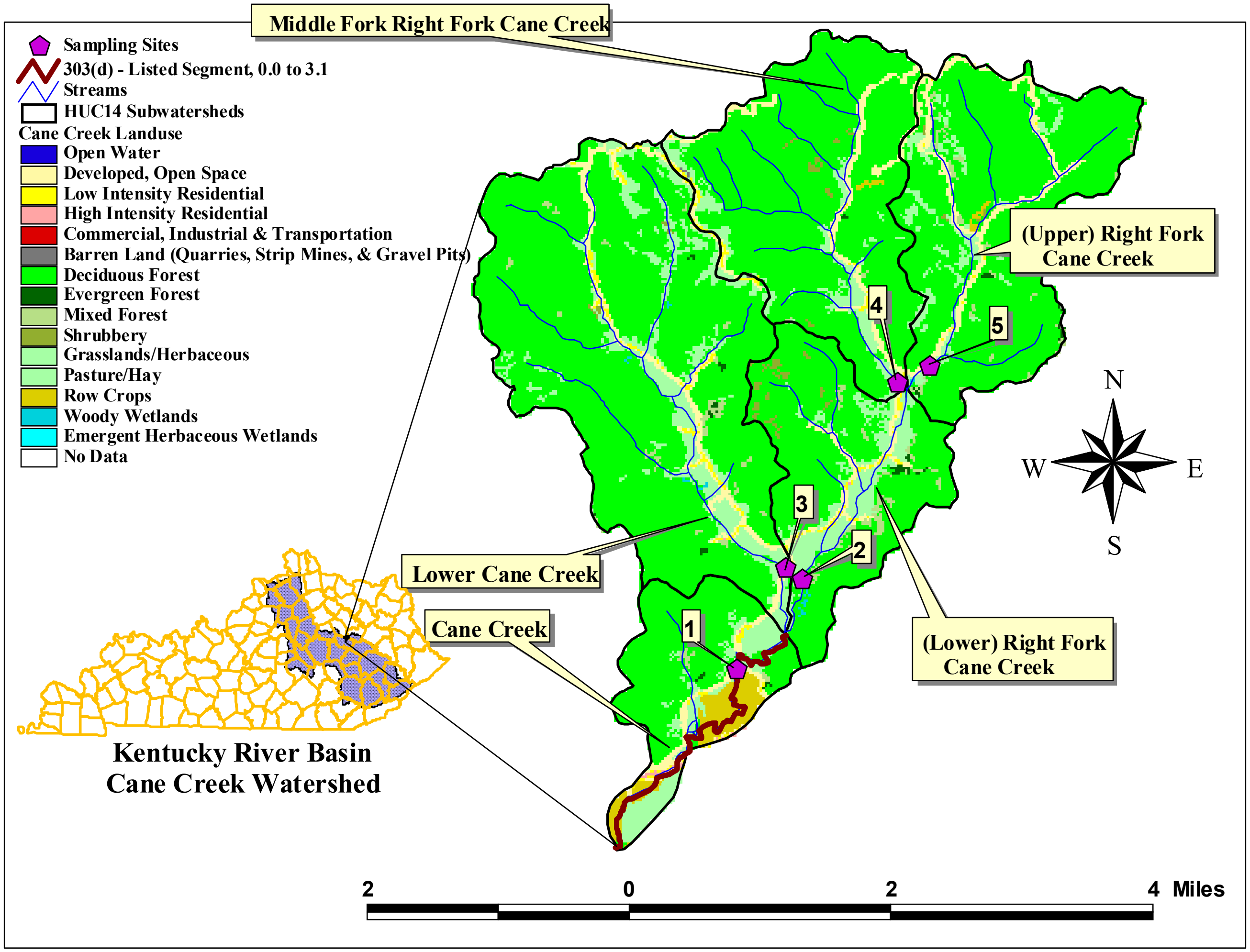

Figure 3.1 Watershed Map

Table 3.1 Stream Configuration

Stream Name	Highest Elevation Point (ft msl)	Lowest Elevation Point (ft msl)	Length, (mi)	Slope (ft/mi)	Drainage Area (mi^2)
Cane Creek	669	640	3.1	9.4	1.4*
Lower Cane Creek	960	669	4.1	71.0	4.8
Middle Fork Right Fork Cane Creek	1087	724	2.8	129.6	2.9
Right Fork Cane Creek	1061	669	5.2	75.4	4.8

*Includes only the drainage area in the Cane Creek HUC14, as shown on Figure 3.1.

The HUC 11 watershed's total area is 13.9 mi^2.

3.2 Geology and Soils

The geology of the Cane Creek watershed is comprised of interbedded sandstone and siltstone ridges underlain by black shale of Devonian age (USDA, 1993). The majority soil type on the ridgetops and ridgeslopes is the Carpenter-Bledsoe-Berks complex, with 20-70% slopes, which is poor soil for farming. Valley soils are mostly comprised of the Grigsby, Newark, Skidmore and Westbend types, all silt-loams with some sandy loams and clay loams. These groups, with the exception of the Westbend group, have good characteristics for farming, although they are floodprone.

3.3 Overall Land Use

The type of land use in Cane Creek was determined by subwatershed; four subwatersheds, corresponding to the major streams in the HUC11, were analyzed. The dataset used was the 2001 National Land Cover Database (NLCD) landuse grid coverage, available in the Kentucky GIS Singlezone Portal, which is based on an analysis of Landsat photography of Kentucky by the United States Geological Survey (USGS, 2003). These subwatersheds are all heavily forested with deciduous trees, and boast a smaller percentage of agricultural land. The Cane Creek subwatershed, being flatter than the other (headwaters) subwatersheds, has a slightly higher percentage of agriculture than the others, but the absence of other landuses is common to all Cane Creek subwatersheds. See Tables 3.2 and 3.3 for a summary of landuse by percentage and landuse by square mile.

Table 3.2 Summary of Landuse by Percentage

Location	Percent						
Subwatershed Name	**Residential**	**Barren Land (Quarries, Strip Mines & Gravel Pits)**	**Forest (Deciduous, Evergreen, Mixed and Shrubbery)**	**Grasslands/ Herbaceous**	**Pasture/Hay**	**Row Crops**	**Woody Wetlands**
Middle Fork Right Fork Cane Creek	7.1%	0.1%	84.5%	3.2%	4.8%	0.3%	0.0%
Right Fork Cane Creek	6.6%	0.0%	83.0%	5.0%	5.1%	0.2%	0.1%
Lower Cane Creek	5.3%	0.0%	82.5%	3.0%	9.1%	0.0%	0.1%
Cane Creek	8.7%	0.0%	58.8%	2.2%	15.6%	14.8%	0.0%

Table 3.3 Summary of Landuse by Square Mile

Location	Square Miles						
Subwatershed Name	**Residential**	**Barren Land (Quarries, Strip Mines & Gravel Pits)**	**Forest (Deciduous, Evergreen, Mixed and Shrubbery)**	**Grasslands/ Herbaceous**	**Pasture/ Hay**	**Row Crops**	**Woody Wetlands**
Middle Fork Right Fork Cane Creek	0.21	0	2.45	0.09	0.14	0.01	0
Right Fork Cane Creek	0.31	0	3.96	0.24	0.24	0.01	0.01
Lower Cane Creek	0.26	0	3.97	0.14	0.44	0	0.01
Cane Creek	0.11	0	0.8	0.03	0.21	0.2	0

4.0 Target Identification

The Water Quality Criteria (WQC) in 401 KAR 5:031 (Kentucky's Surface Water Standards) for the PCR use are based on both fecal coliform bacteria and Escherichia (E.) coli bacteria. For this TMDL, the E. coli criterion was applied. This criterion states that, for the PCR designated use:

"[The] Fecal coliform content or Escherichia coli content shall not exceed 200 colonies per 100 ml or 130 colonies per 100 ml respectively as a geometric mean based on not less than five (5) samples taken during a thirty (30) day period. Content also shall not exceed 400 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period for fecal coliform or 240 colonies per 100 ml for Escherichia coli. These limits shall be applicable during the recreation season of May 1 through October 31."

There are insufficient water quality data to calculate a 5-sample, 30-day geometric mean, so the latter criterion of 240 colonies/100 ml was used as the TMDL target in order to calculate percent load reductions to bring the watershed into compliance with the PCR designated use. However, this value (and thus the TMDL Target) are expressed as a load (i.e., based on both concentration and flow), as opposed to a concentration only, see Section 8.1, below.

5.0 Monitoring

5.1 Previous Monitoring

Cane Creek was listed on the 2002 303(d) based on an assessment performed in August of 1998 by the Water Quality Branch of the Kentucky Division of Water (KDOW). The location sampled was RM 2.4 at the State Route 599 Bridge, which is a rotating biological and water quality monitoring station, designated KRW011, Cane Creek Near Bowen. The biology showed full support and the habitat showed no impairment, but cows were observed in the creek. Also, pathogens were sampled monthly from May 1998 through October 1998; of these 6 samples, 3 were exceedances of the instantaneous maximum allowable instream fecal coliform concentration of 400 colonies/100ml (see Appendix B for these data). This prompted the listing for pathogens. However, these fecal coliform results were not used in this TMDL because E. coli was analyzed instead of fecal coliform during TMDL monitoring, and while the two parameters are correlated, the simultaneous data needed to determine a correlation coefficient were not available.

5.2 TMDL Monitoring

Monitoring for this TMDL involved five sampling locations, one in each HUC14. This placed two sampling stations on Right Fork Cane Creek, which is represented by two HUC14s, see Figure 3.1. Monitoring began in May of 2005 and concluded in September of 2005. In all, 10 samples were taken per site (when water was present, see Appendix B for sampling data). Parameters collected included flow, temperature, pH, dissolved oxygen, % oxygen saturation, and E. coli bacteria. An exceedance summary is presented in Table 5.1. This summary shows which additional stream segments in the watershed were found to be impaired based on the 2005 data (i.e., segments listed as “partial support” or “nonsupport” are impaired). Note Cane Creek RM 0.0 to 3.1 was already assessed as impaired for the PCR use, but the percent exceedance rate for this segment is included in Table 5 because if the new data showed a change in the stream’s status then it would have been reassessed and assigned a new support designation. However, the new data result in the same assessment as the original data.

The support status determinations were made by comparing the 2005 sample results to the E. coli instantaneous maximum concentration of 240 colonies/100ml, as less than 5 samples were collected in a 30-day period, thus the 30-day geometric mean could not be calculated. Stream segments with less than or equal to 20% exceedances were assessed as fully supporting the PCR designated use. Stream segments with greater than 20% but less than 33% exceedances were assessed as partially supporting the PCR use. Segments with 33% or greater exceedances were assessed as not supporting the PCR use (KDOW, 2006). Figure 5.1 shows stream segment assessments using the 2005 monitoring data.

Table 5.1 Stream Segment Assessments, 2005 Data

Station	Stream Name, River Miles Assessed	Samples	Exceedances	Percent Exceedances	PCR Use Assessment
1	Cane Creek of Red River, RM 0.0 to 3.1*	10	8	80%	Not Supporting
2	(Lower) Right Fork Cane Creek of Cane Creek, RM 0.0 to 2.2	10	1	10%	Fully Supporting
3	Lower Cane Creek of Cane Creek, RM 0.0 to 4.1	10	6	60%	Not Supporting
4	Middle Fork of Right Fork Cane Creek, RM 0.0 to 2.8	8	3	37.5%	Not Supporting
5	(Upper) Right Fork Cane Creek of Cane Creek, 2RM 2.2 to 5.2	9	2	22.2%	Partially Supporting

*Assessed as impaired in Kentucky's 2002 303(d) report, current data does not change support status.

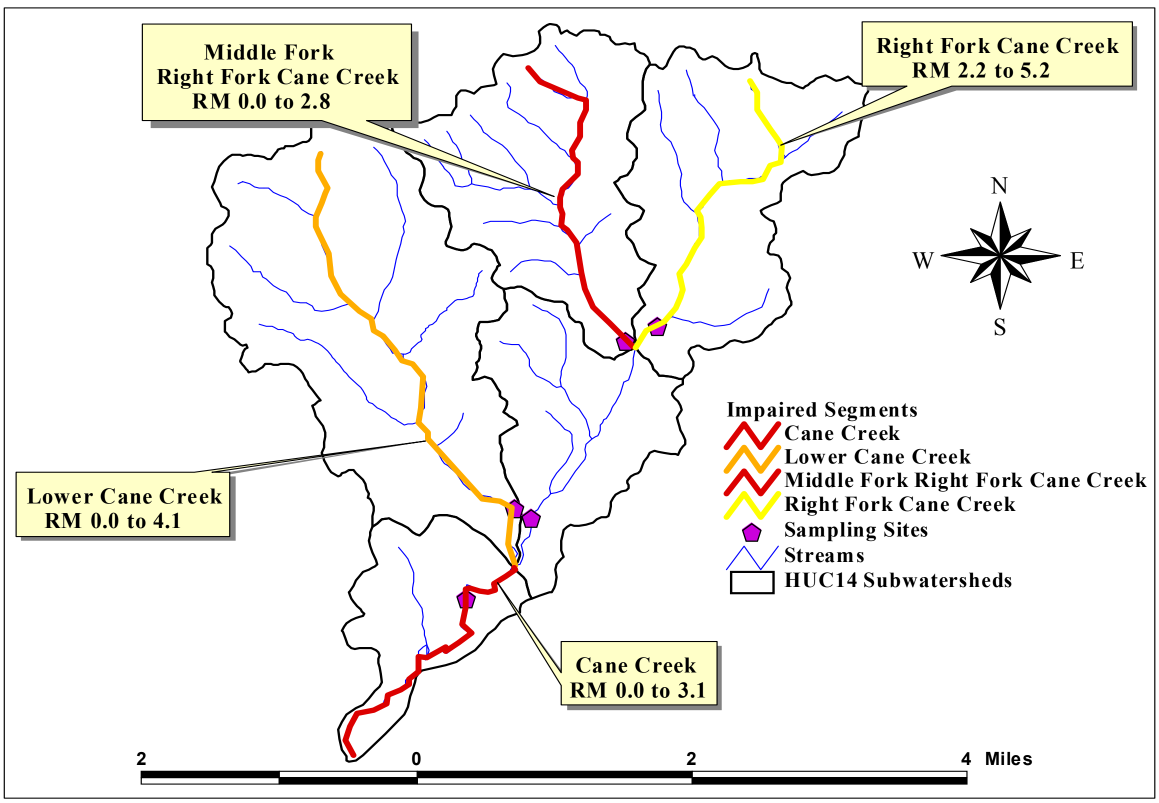

Figure 5.1 Impaired Stream Segments

6.0 Source Identification

6.1 Permitted Sources

Permitted sources include all sources regulated by the Kentucky Pollutant Discharge Elimination System (KPDES) permitting program. KPDES specifically regulates point sources, and according to 401 KAR 5:002, a point source is "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, or concentrated animal feeding operation [CAFO], from which pollutants are or may be discharged. The term does not include agricultural storm water run-off or return flows from irrigated agriculture." No permitted point sources of any kind exist within the Cane Creek watershed.

6.2 Non-permitted Sources

Non-permitted sources include all sources not permitted by the KPDES permitting program, and are often referred to as nonpoint sources. According to 401 KAR 5:002, nonpoint means "any source of pollutants not defined as a point source, as used in this chapter." While KPDES permits are not required for non-permitted sources, their loads to surface water are still regulated by laws such as the Kentucky Agricultural Water Quality Act (i.e., implementation of individual agriculture water quality plans and corrective measures), the federal Clean Water Act (i.e., the TMDL process) and 401 KAR 5:037 (Groundwater Protection Plans), among others. Unlike permitted sources, non-permitted sources typically discharge pollutants to surface water in response to rain events. Non-permitted sources for pathogens exist in the watershed, and fall into various categories including agriculture, human waste disposal, household pets and natural background, which in the case of pathogens in a rural watershed means wildlife. These non-permitted sources are correlated to landuse.

Note KPDES is not the only permitting program for sources that may discharge to surface water within a watershed, or otherwise affect water quality or quantity. Other permitting examples include water withdrawal permits, permits to build structures within a floodplain, and permits to land apply waste from sewage treatment plants. However, for purposes of this TMDL, the definition of a permitted source as opposed to a non-permitted source is derived from the application of the KPDES program.

6.2.1 Agriculture

According to the 2002 United States Department of Agriculture (USDA) Agricultural Census of Powell County, Kentucky, there are 2514 cattle or calves within the county boundaries, located on 86 farms. There were 2 hog farms (although the number of hogs was withheld in the report to avoid disclosing data for individual farms).

In the absence of other data, these numbers could be used to estimate the number of cows and hogs in each subwatershed. However, data gathered through direct observation is preferred when available, and reconnaissance of the watershed performed during the September 20th, 2005 sampling event noted the following information:

- There were approximately 15-20 cows between Stations 1 and 2 (in the Cane Creek subwatershed) which had access to the creek.
- There were approximately 20 horses in the lower Right Fork Cane Creek watershed, above Station 2, which also had access to the creek.
- Anecdotal evidence indicated the likely presence of hogs in the Lower Cane Creek subwatershed (which is represented by Station 3).
- Besides the fields which contained the animals mentioned above, fields in the watershed did not appear to be pathogen sources due to grazing: They were either planted in hay or were fallow.
- Row crops were, for the most part, limited to plots suitable in size for family gardens as opposed to commercial agriculture, so manure application for crop fertilization probably played a minimal role in contributing pathogens to the surface water at the time of this study.

No other farm animals were observed in the watershed.

6.2.2 Human Waste Contribution

Although the population in the watershed is low, the watershed is not sewered (KIA, 2005), so failing Onsite Sewage Treatment and Disposal Systems (OSTDS) are likely sources of pathogens. Septic systems are a common example of OSTDS, but several other types exist. According to the Powell County Health Department (Rusty Griffith, Personal Communication, 2005), most of the County has shallow soil with a high percentage of clay and shale, and in the majority of cases there is insufficient topsoil to install a septic system without a very high percentage of soil amendment—such amendment often must be hauled in over great distances, increasing installation costs. Further complicating the proper installation of septic systems is the fact that Powell County has no locally mandated minimum lot size that can be zoned for installation of a septic system, thus a landowner with any size lot can legally install one. A house count based on the topographic maps of the watershed shows 55 houses, and based on the average number of persons per household (2.64) from the US Census Bureau (2000), the watershed contains an estimated 145 people.

Further, USDA (1993) states that the Newark, Grigsby, Skidmore and Westbend soils (which comprise the majority of the valley floor soils in this watershed) all severely restrict installation of septic tank absorption fields due to flooding and wetness.

A type of non-permitted source that may exist in the Cane Creek watershed is straight pipes, which are discrete conveyances that discharge sewage, gray water (i.e., water from household sinks, laundry, etc.) and stormwater to the surface waters of the Commonwealth without treatment. Although straight pipes meet the definition of a point source as defined in 401 KAR 5:002, EPA considers them to be a nonpoint source for load allocation purposes within a TMDL. However, straight pipes are illegal, as are discharges from failing septic systems, and thus they receive an allocation of zero, see Section 8.2.3.1. There may be straight pipes within the Cane Creek watershed, but none are known to exist with certainty.

There are no landfarming permits issued by the Kentucky Division of Waste Management for wastewater treatment plant sludge in the watershed (Bob Bickner, Personal Communication, 2006), nor are there domestic septage disposal sites in Powell County (Rusty Griffith, Personal Communication, 2006).

6.2.3 Household Pets

Although household pets undoubtedly exist in the watershed, their contribution is deemed to be minimal compared to the other sources based on the low number of households per square mile.

6.2.4 Wildlife

Wildlife undoubtedly contribute pathogens to the watershed, noting the high percentage of forest in all subwatersheds. The Kentucky Department of Fish and Wildlife Resources states there are an estimated 12 deer per square mile in Powell County (David Yancy, Personal Communication, 2006). Extrapolating this number to the watershed as a whole produced an estimated 167 deer. Estimates on numbers of other types of animals are not available. As stated above, although wildlife contribute pathogens to surface water, such contributions are considered to be background and therefore wildlife receive no percent reduction within the TMDL.

7.0 Data Analysis

7.1 Methods

E. coli results were analyzed using the Load Duration Curve (LDC) method. The LDC is a data analysis tool that plots the load of E. coli observed at a particular sampling station (by combining an E. coli concentration with the stream's flowrate at the time the sample was collected to generate load) versus a curve which represents the maximum allowable load that would be permitted in the creek under similar flow conditions (this curve is generated by multiplying the WQC of 240 colonies/100ml by the recorded flow values in the creek). This allows a graphical interpretation of the difference between the existing load and the WQC.

In order to build a LDC, a Flow Duration Curve is built first. This involves finding all recorded flow values within a creek at a particular sampling station and calculating the percent rank of each value. This percent rank is plotted on the X-axis of a graph, and the corresponding flow is plotted on the Y-axis using a $\log_{10}$ scale. This procedure displays higher flows on the left part of the graph, and lower flows (and the period where the creek goes dry, if any) on the right part of the graph. Multiplying this flow curve by the WQC gives the WQC as a load (which is converted from units of (colonies-ft^3)/(100ml-second) to billions of colonies per day), and is the basis for the LDC. To complete the LDC, the sample results are plotted at their corresponding flow values, thus exceedances of the WQC plot above the curve, and vice versa.

The LDC is divided into five flow zones (also called flow conditions); High Flows (which are flows that are not exceeded for more than 10% of the period of record, on the far left part of the graph), Moist Conditions (with flows exceeded between 10% and 40% of the period of record), Mid-Range Flows (which are exceeded between 40% and 60% of the period of record), Dry Conditions (with flows exceeded between 60% and 90% of the period of record), and Low Flows (which are exceeded between 90% and 100% of the period of record, on the far right part of the graph). Dividing the curve into zones allows a graphical determination of the critical period from among wet, medium-range, or dry weather conditions by plotting the samples which exceeded the WQC; in the case of Cane Creek, the highest exceedance(s) relative to the WQC at a given station were used to determine the critical period, see Section 8.2.1, below.

Dividing the curve into flow zones also gives insight into the sources of the pollutant, since most sources are known to cause the most impairment at one or two zones of the LDC. For instance, permitted point sources, cattle with direct access to streams and straight pipes have the greatest impact during dry, low-flow conditions (i.e., the Dry Conditions and Low Flows zones of the LDC), and most nonpoint sources (such as agricultural runoff) typically have their greatest impact on creeks during wet weather when overland flow transports pollutants into the creek (i.e., the High Flows and the Moist Conditions zones).

However, the LDC requires the user to have flow data over a large time period (e.g., many years) in order to differentiate between wet, medium-range and dry conditions in a given creek, and flow gages are seldom available in impaired watersheds. To address this common data gap, often a nearby flow gage is found whose measured flow is significantly correlated to the flow in the ungaged (i.e., TMDL) watershed. For this project, the flow gage at Hazel Green (USGS Gage #03282500) on the Red River was found to be the most appropriate gage to use for comparison purposes as it showed an excellent correlation with flow data collected in Cane Creek from May, 2005 through August, 2005 (see Appendix A, the Modeling Report), and thus was used to generate the LDCs at the Cane Creek sampling stations using proportional area flows. Other nearby gages that were considered were located on the Kentucky River, a much larger system, and on the Licking River, which is in a different major basin with gages affected by flow regulation of the Cave Run Lake dam. See Section 8.2.5.1 below for a discussion of uncertainty involved in the LDC method. See Table A.6 for a summary of samples per flow zone at each station and the percent exceedances by flow zone at each station. See also Appendix B for the analytical data used in TMDL development and additional discussion of data analysis.

8.0 TMDL

8.1 TMDL Equation

A TMDL calculation is performed as follows:

$$TMDL = WLA + LA + MOS$$

Where

TMDL = the WQC expressed as a load. This was defined in Section 4.0 as the loading that is equivalent to a concentration of 240 colonies/100ml at a given flow, in units of billions of colonies per day.
WLA = the WasteLoad Allocation, which is the allowable loading of pollutants into the stream from permitted point sources such as sewage treatment plants and Municipal Separate Storm Sewer Systems (MS4s). As stated, no permitted point sources exist in this watershed.
LA = the Load Allocation, which is the allowable loading of pollutants into the stream from non-permitted sources and natural background.
MOS = the Margin Of Safety, which can be an implicit or explicit additional reduction applied to sources of pollutants that accounts for uncertainties in the data or TMDL calculations.

Percent reductions are applied to sources to bring existing conditions in line with the **TMDL Target Load**, which is defined as the TMDL minus the MOS. After these reductions are calculated, the WLA (if any) and LA (if any) represent the final allocation for sources in the watershed (i.e., the allowable loading to the stream system for those sources).

The TMDL calculation must take into account seasonality and other factors that affect the relationship between pollutant inputs and the ability of the stream to meet its designated uses. This typically involves defining a critical condition, see below.

8.2 TMDL Components

8.2.1 Critical Condition

The critical condition (or critical period, which in this case will be defined as a flow condition) was selected as the LDC zone at each station with the highest pollutant load relative to the WQC (i.e., the zone with the highest sample exceedance relative to the WQC, since load is proportional to concentration), and thus the highest percent reduction needed to achieve the TMDL target load (see Section 8.2.4 for the method used to calculate percent reductions). The TMDL percent reduction for each station was then defined based on the LDC zone selected as the critical condition, since all other zones should theoretically meet the PCR designated use if the percent reduction needed at the zone with the highest sample exceedance is applied to all other zones at that station. However, a TMDL target load (and, if appropriate, the percent reduction needed to achieve that target load) was derived for all flow conditions at all stations, and these data are included in Appendix A.

8.2.2 Existing Conditions

Existing conditions include sources documented or reasonably inferred at the time of the study. The loading under existing conditions is categorized into the Permitted Source Load and the Non-Permitted Source Load (which are not synonymous with the WLA and the LA, see Section 8.2.3 below for further discussion). As stated, there are no permitted point sources in the watershed. The pollutant contribution from other sources (household pets, wildlife, and agriculture, failing septic systems and possibly straight pipes) are represented under the Non-Permitted Source Load. Percent reductions from these existing conditions (and from any new sources that may be introduced into the watershed subsequent to this study) should be effected until the final allocations are achieved and the watershed meets the PCR designated use.

8.2.3 WLA and LA

The WLA and LA represent the final pollutant loading allocations that are allowed in the watershed. The WLA and LA are different than the initial loadings to the watershed (which are causing the impairment, either individually or in sum), instead they are the final allocations (which are set at a level that will ameliorate the impairment).

8.2.3.1 Illegal Sources. Both WLA and LA sources can discharge pathogens to surface water illegally. Within the LA, two illegal sources related to human waste disposal include failing OSTDS and straight pipes, which receive an allocation of zero. In the course of eliminating any existing straight pipes or failing OSTDS, the pollutant load carried could be routed to functional OSTDS, to an existing WWTP, or possibly to a future KPDES-permitted point source such as a package treatment plant. If the former, the load will be reduced between 99% and 99.9%, after pathogen losses in the soil column are accounted for (EPA, 2002). If the latter, the permitted point source must conform to the requirements for point sources as described in the WLA, below. Other potential illegal sources within the LA are failing, non-existing or underperforming 'Best Management Practices' (BMPs). Illegal sources can also occur within the WLA (examples being Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)) but there are no permitted sources within this watershed

Note this Section of the TMDL is not intended to summarize the universe of potential illegal sources that may discharge pollutants into surface waters, nor does it attempt to summarize the universe of permitted sources that may be operating illegally (e.g., outside of permit limits or conditions, etc.). Instead, it defines the illegal sources known to be present in this watershed (or in the case of straight pipes, sources that could be present in the watershed based on the soil type, topography and landuse conditions) and sets the allocation for these (and other potential illegal sources) at zero.

8.2.3.2 WLA. The WLA is the allocation given to KPDES-permitted point sources within the TMDL. As stated, there are no permitted point sources in the watershed, so no loading—and thus no load reduction from existing conditions—can be applied to the WLA portion of the TMDL calculation. In the future, permitted source(s) may be allowed in the watershed, but any such source would be required to meet permit limits based on the Water Quality Standards in 401 KAR 5:031 and must not cause or contribute to an existing impairment.

8.2.3.3 LA. The LA is where non-permitted sources (e.g., nonpoint sources, or those sources not permitted by KPDES) receive their allocation within the TMDL. In the case of Cane Creek, non-permitted sources include human waste disposal, household pets, wildlife and agriculture. The contribution from household pets is deemed to be minimal, and loading from wildlife is considered to be background and receives no load reduction, thus the majority of reductions from existing conditions are expected to come from the 100% elimination of illegal sources related to human waste disposal and agriculture, as stated above.

The available sampling data were insufficient to apportion the existing loading among the various sources. Therefore, the percent reduction necessary to achieve the allowable load was calculated from all sources as opposed to individual sources, even though some sources (e.g., wildlife) are not expected to have controls implemented as a result of this TMDL.

8.2.4 Calculation of the TMDL Target Load and Percent Reductions by Station

At each station along an impaired segment (i.e., at all stations except Station 2), a TMDL Target Load was calculated for each zone within the LDC (see Appendix A) and percent reductions needed to achieve the TMDL Target Load were calculated if there were samples in that zone which exceeded the WQC. The highest percent reduction to achieve the TMDL Target Load in all zones at each station was reported in Table 8.1. However, at ten samples per station and five flow zones within each LDC, not every zone had a sample (or samples) within it, and not all of the samples showed exceedances of the WQC. Therefore, three different methods were used to set the TMDL Target load within each zone (and to calculate a percent reduction, if applicable):

<u>No exceedances within a zone</u>: In the case where there were no samples showing exceedances within a flow zone at a station, the TMDL Target Load for that zone was set as the 90th percentile of all loads within that zone at the WQC minus the MOS (see Section 8.2.5.3 below). Since the existence and magnitude of any possible violations of the WQC could not be determined, no percent reduction was calculated.

<u>One exceedance within a zone</u>: If there was one sample that exceeded the WQC within a flow zone at a station, the TMDL Target Load was set as the load at the WQC that corresponds to the flow percentile of the sample, minus the MOS. A percent reduction was calculated as the difference between the sample load and the TMDL Target Load.

<u>Two or more exceedances within a zone</u>: If there were two or more samples that exceeded the WQC within a flow zone at a station, the TMDL Target Load was set as the load at the WQC that corresponds to the 90th percentile of the flow percentiles of the samples, minus the MOS. The percent reduction was calculated as the difference in load between the 90th percentile of the sample loads and the TMDL Target Load.

The LDCs in Section 8.3 show the data used for each station to set the TMDL Target Load and percent reduction for each zone, if applicable. Raw data is also presented in Appendix B. Table A.6 shows the percent exceedances for all zones at each station.

8.2.5 Margin of Safety

As stated, the MOS can be an implicit or explicit additional reduction applied to the WLA, LA or to both types of sources that accounts for uncertainties in the data or TMDL calculations. Below is a discussion of uncertainty and other factors accounted for by the MOS.

8.2.5.1 Accounting for Uncertainty in the MOS

Uncertainties in the LDC Method: While the Red River is the most appropriate system to compare to Cane Creek, one weakness of using a gage on the Red River to generate flow data for the Cane Creek stations is the Red River drains a 65.8 mi^2 watershed at Hazel Green and Cane Creek is a 13.9 mi^2 watershed. Thus Cane Creek (and especially its headwater tributaries) will go dry before the Red River at the Hazel Green gage, which has gone dry for less than one percent of its period of record (1954-present). This discrepancy will artificially shift the flow duration curves for the Cane Creek sampling sites to the right (indicating the presence of flow where, in some dry periods, no flow actually exists). This makes it somewhat more difficult to define the critical period, and may artificially decrease the percent reduction called for to achieve TMDL goals. As a result, an explicit Margin of Safety (MOS) was included in the TMDL calculation, see Section 8.2.5.3 below. However, despite this drawback, the LDC method was used because it retains the strengths of allowing graphical data analysis and allows much to be inferred about the critical period and potential sources.

Uncertainties in the TMDL Calculations: The reductions needed to achieve the TMDL Target were calculated using one to three samples per flow zone. One to three samples is a very small dataset with which to calculate reductions, and this increases the uncertainty involved. Because of this, an implicit and explicit MOS will be included to account for the small size of the dataset. However, regardless of the procedure used to estimate percent reductions for each sampling station, reductions from existing conditions ultimately must be effected within the watershed only until all stream segments meet the PCR use, or until all sources save wildlife are discharging in compliance with the WQC. However, once the WQC is met, all sources (save wildlife) must continue to discharge at a load that meets the WQC.

8.2.5.2 Other Factors Accounted for by the MOS

Only samples which showed exceedances of the criterion were used to calculate the percent reductions at each station, as opposed to using all the data. As stated above, in some flow zones only one exceedance was found, and where this occurred, this value alone was used to calculate the percent reduction for the zone. To the extent that the sampling data represent actual conditions, these procedures will generate an implicit MOS. In addition, duplicate samples were taken along with the first sample and every ten samples thereafter: The higher of the two duplicate values was used for TMDL development, resulting in an additional implicit MOS. However, these factors are balanced to a degree by using proportional area flows from a gaged stream which goes dry less often than the streams in the TMDL watershed and by the small analytical dataset.

8.2.5.3 Determination of the MOS

To account for the use of proportional area flows from a larger watershed and for the small dataset, an explicit MOS of 10% will be applied to the final reductions at all stations. This is in addition to the implicit MOS from using only samples that showed exceedances of the criterion to calculate percent reductions.

8.3 LDCs Showing TMDL Data

Below are the LDCs showing the data collected for the TMDL, along with the critical condition for each station, with the exception of Station 2, which fully met the PCR use. Also, the probable source(s) of E. coli at each station are discussed based on the flow zone(s) that showed exceedances of the WQC. However, the number of samples obtained for this TMDL was far too small to rule out the possibility of contribution from the other known sources of E. coli bacteria discussed in Section 6.0 for any given station. Thus, even if a source was not discussed below, it still may contribute pathogens to the watershed. Further, no meaning should be inferred from the order in which the sources described in this Section are presented, since the relative contribution of a given source to the total E. coli load is unknown, even if some sources (such as household pets) are expected to contribute less than others.

The LDC figures are generated on a log-normal scale, with percent flow rank on the (normal) x-axis and E. coli load on the ($\log_{10}$) y-axis. This has the advantage of showing the entire spectrum of loads on the same graph. However, it can be difficult to determine the magnitude of the sample loads relative to the load at the WQC (which is proportional to the percent exceedance of a given sample relative to the WQC) by visual inspection. This means the critical condition can be difficult to determine by use of the LDC graph alone. Appendix B contains the sample concentration data used to generate the LDC sample loads along with the percent flow rank of each sample, and these data can be consulted in the event the highest exceedance of the WQC (and thus the critical condition) at a given station is unclear.

8.3.1 Station 5

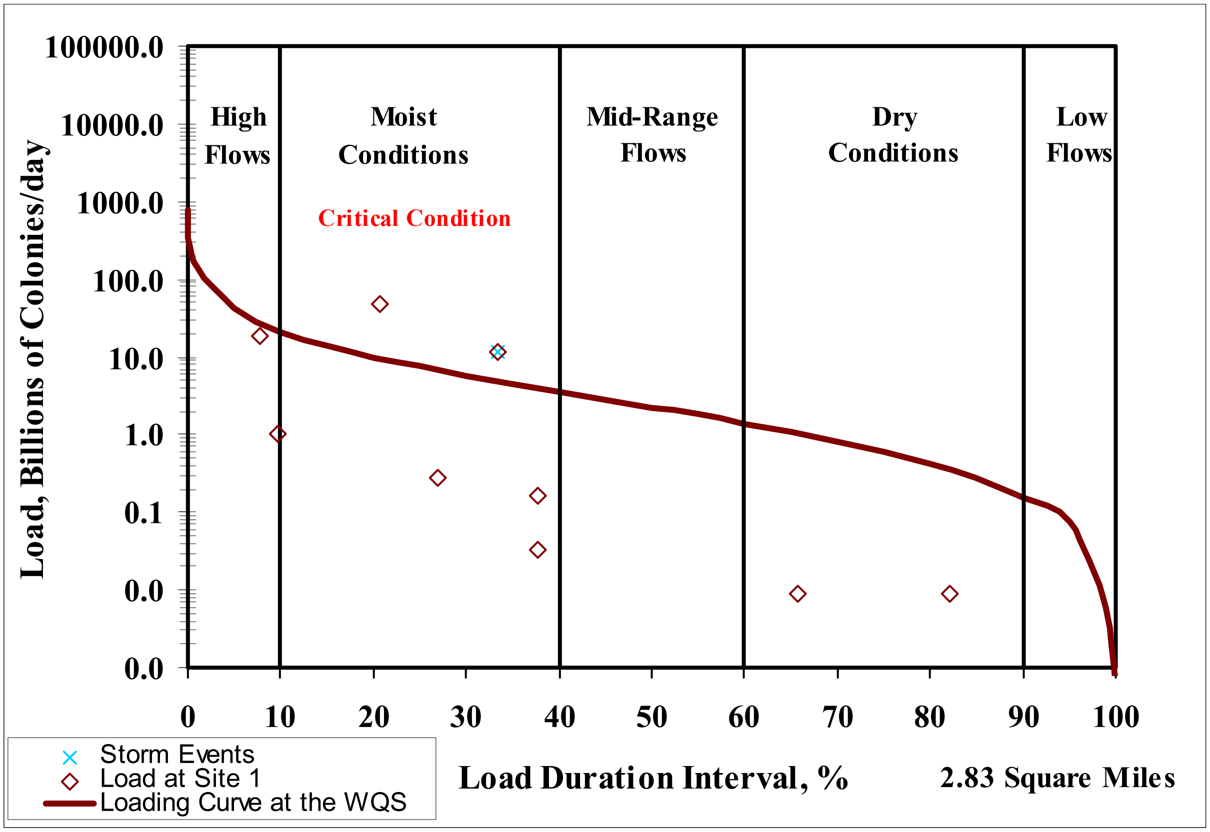

Figure 8.1 LDC for Station 5, (Upper) Right Fork Cane Creek of Cane Creek

As shown on Figure 8.1, the only exceedances were present in the Moist Conditions zone, which is therefore the critical period for this station. Based on this critical period, probable sources include failing septic systems, livestock, household pets and wildlife.

8.3.2 Station 4

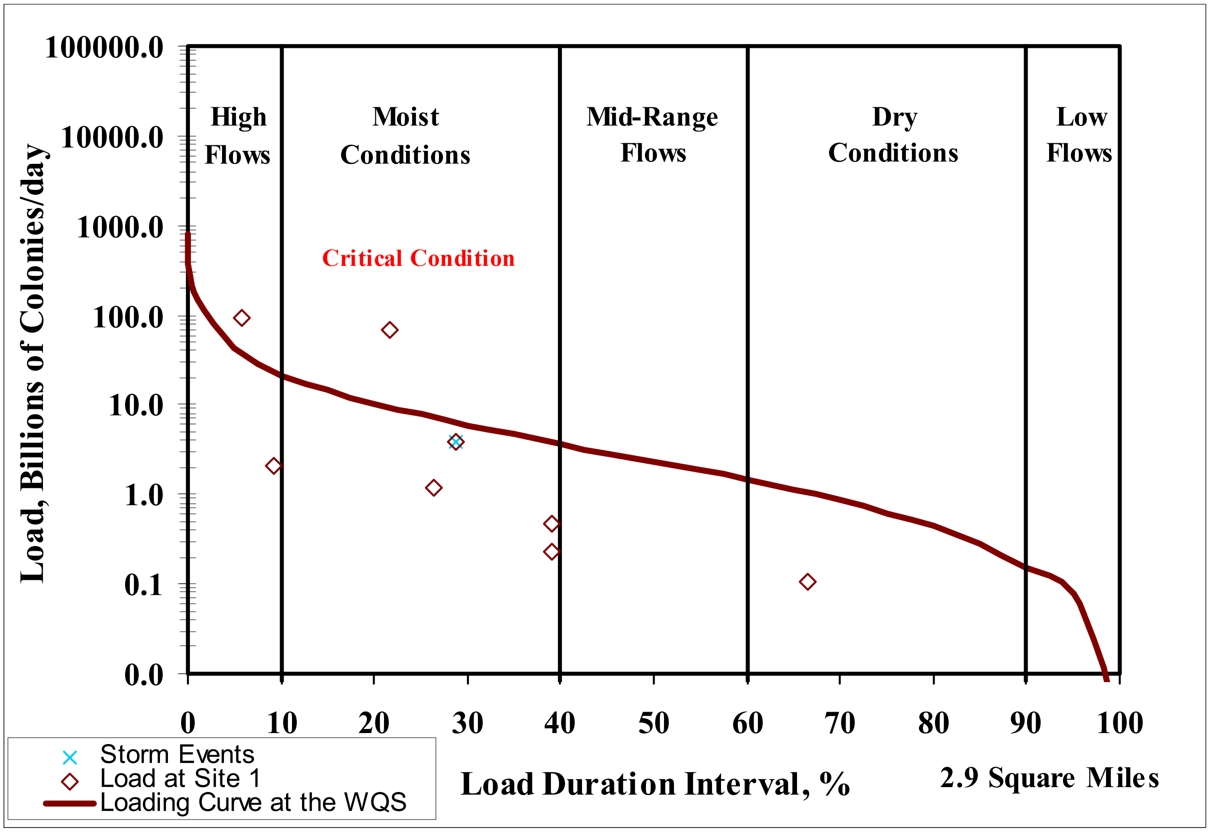

Figure 8.2 LDC for Station 4, Middle Fork of Right Fork Cane Creek

As shown on Figure 8.2, the greatest reduction needed to bring all zones into compliance with the WQC was in the Moist Conditions zone, which is therefore the critical period for this station. Based on this critical period, probable sources include failing septic systems, livestock, household pets and wildlife.

8.3.3 Station 3

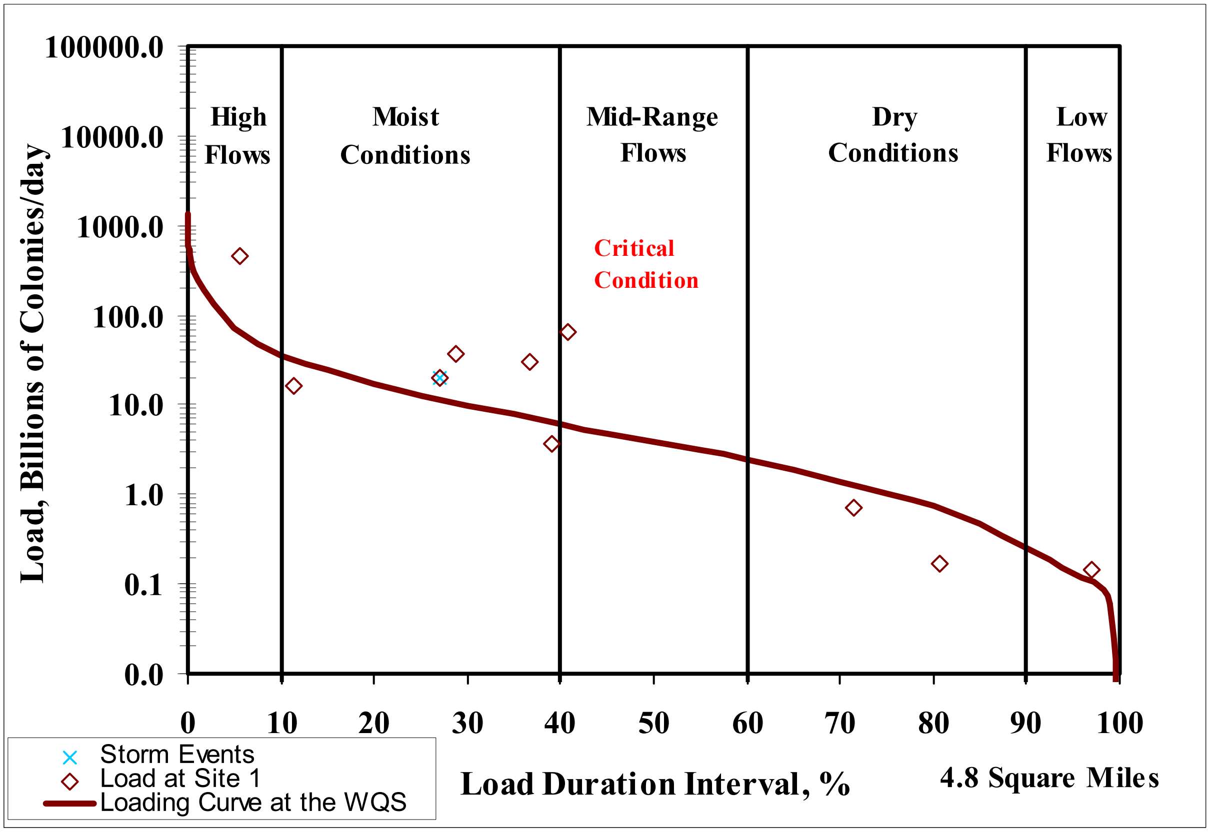

Figure 8.3 LDC for Station 3, Lower Cane Creek of Cane Creek

As shown in Figure 8.3, the sample with the greatest exceedance was in the Mid-Range Flows zone, which is therefore the critical period for this station. Based on this critical period, probable sources include failing septic systems. However, based on the lesser exceedances (relative to the WQC) observed in other flow zones such as the Moist Conditions and High Flows, other sources (such as livestock, household pets and wildlife) are also present in this subwatershed. These sources deposit E. coli onto the watershed during dry periods which are later carried to the stream by rainfall runoff, thus the instream concentrations increase during wetter conditions.

8.3.4 Station 2

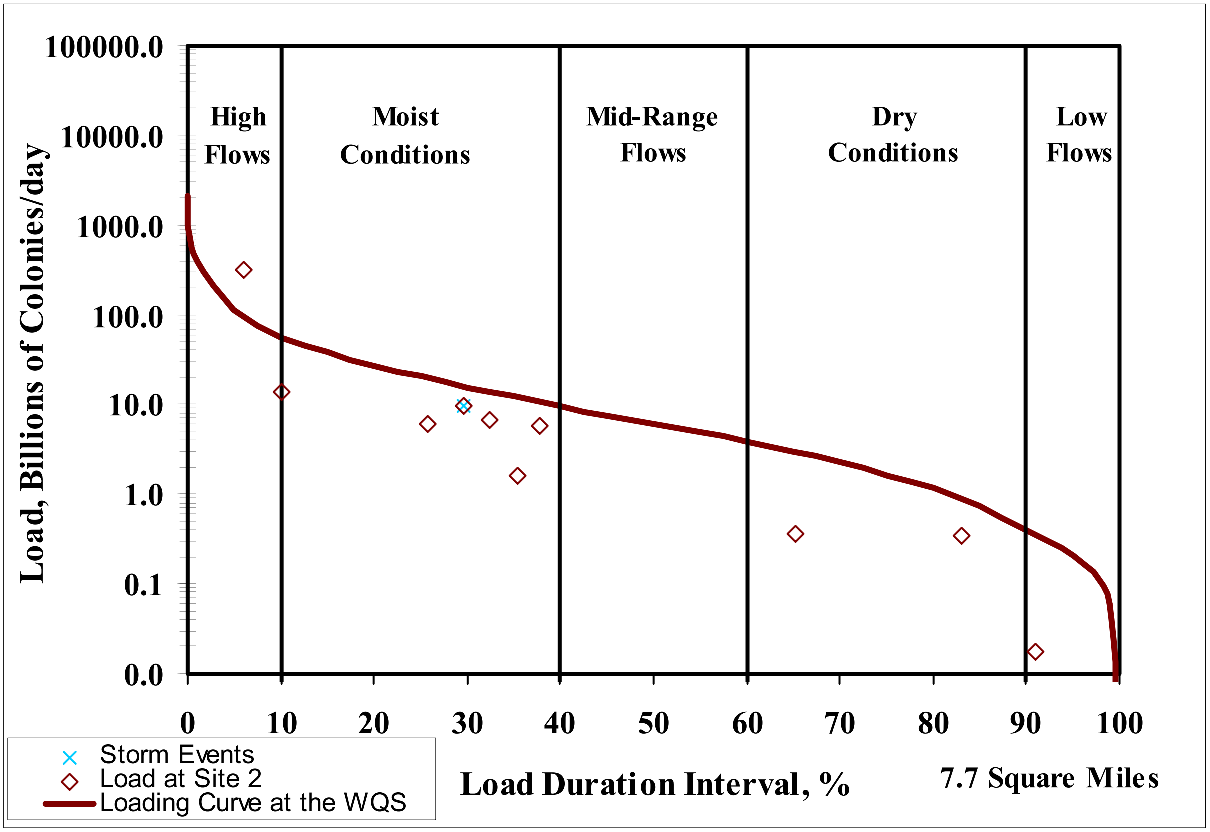

Figure 8.4 LDC for Station 2, (Lower) Right Fork Cane Creek of Cane Creek

As shown on Figure 8.4, the only exceedance was during High Flows, indicating possible sources include wildlife, livestock or household pets. However no cattle were observed in the watershed upstream of Station 2, making household pets and wildlife the likeliest sources. Because only one sample out of ten showed an exceedance, the stream segment represented by Station 2 (i.e., Right Fork Cane Creek RM 0.0 to 2.2) fully supports the PCR designated use as described in Section 5.2, and therefore no critical condition exists.

8.3.5 Station 1

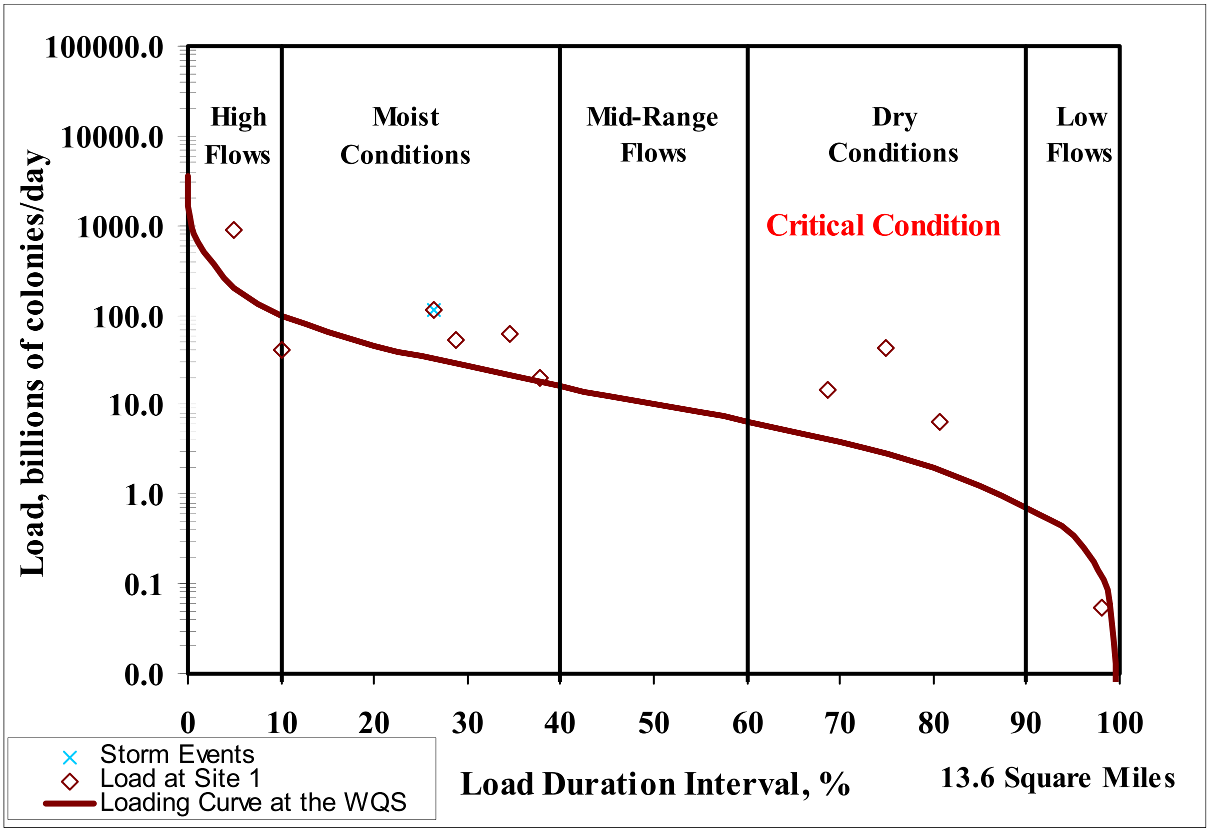

Figure 8.5 LDC for Station 1, Cane Creek of Red River

As shown on Figure 8.5, the sample with the greatest exceedance of the WQC was in the Dry Conditions zone, which is therefore the critical period for this station. Based on this critical period, probable sources include straight pipes and livestock with direct access to the stream, in addition to the sources defined for the more upstream stations. As with Station 3, however, there were also exceedances in the wetter flow zones, indicating other sources (such as livestock, household pets, and wildlife) are also likely contributing E. coli to the stream.

8.4 Extending Loads to the Bottom of the Impaired Segments

The sampling stations used for this report were not uniformly located at the bottom of the impaired segments they represent. Thus the argument could be made that any TMDL calculation performed at the station does not represent the entire impaired segment. To address this potential concern, the TMDL calculations (i.e., the Existing Conditions, TMDL Loads, MOS and LA) have all been multiplied by the ratio of the drainage area of the end of the impaired segment to the drainage area of the sampling station that represents the impaired segment (drainage areas were calculated from USGS, 2007), as shown in Table 8.6, below. The changes made as a result of this procedure are reflected on the final TMDL Table (Table 8.7), but they are not reflected in the individual tables in Appendix A, which are composed of unmodified data. No drainage area ratio was computed for Station 2 as it does not lie on an impaired segment.

Table 8.6, Drainage Area Ratios

Site Number	Site Drainage Area	Subwatershed	Subwatershed Drainage Area	Drainage Area Ratio
5	2.68	(Upper) Right Fork	2.8	1.045
4	2.90	Middle Fork Right Fork	2.9	1.000
3	4.75	Lower Cane Creek	4.8	1.011
2	N/A*	(Lower) Right Fork	N/A	N/A
1	13.00	Cane Creek	13.9	1.069

*Not Applicable

8.5 TMDL Summary by Station

Below is a table defining the TMDL for the watershed. As stated, the maximum reduction for all zones at a station was used as the TMDL (i.e., the overall percent reduction) for that station.

Table 8.7 Final TMDL Summary by Station

Location		Existing Conditions		TMDL = WLA + LA + MOS				TMDL Target	Percent Reduction Needed to Achieve TMDL Target	
Station Name	Subwatershed	Load (billion colonies/day)		TMDL (WQC as a Load) (billion colonies/day)	Final Allocation (billion colonies/day)		MOS[2] (billion colonies/day)	TMDL Target Load (WQC minus MOS) (billion colonies/day)	Percent Reduction (billion colonies/day)	
		Wasteload	Load		WLA[1]	LA			WLA	LA
5	(Upper) Right Fork Cane Creek of Cane Creek	0	50.31	10.06	0	9.06	1.00	9.06	0%	82.0%
4	Middle Fork of Right Fork Cane Creek	0	68.69	9.51	0	8.56	0.95	8.56	0%	87.5%
3	Lower Cane Creek of Cane Creek	0	65.79	5.64	0	5.08	0.57	5.07	0%	92.3%
1	Cane Creek	0	39.24	4.22	0	3.80	0.42	3.80	0%	90.3%

[1]Any future permitted point source must meet permit limits based on the Water Quality Standards in 401 KAR 5:031, and must not cause or contribute to an existing impairment.
[2]An explicit MOS of 10% was used, along with an implicit MOS from using a conservative method to calculate existing conditions.

9.0 Implementation

Section 303(e) of the Clean Water Act and 40 CFR Part 130, Section 130.5, require states to have a continuing planning process (CPP) composed of several parts specified in the Act and the regulation. The CPP provides an outline of agency programs and the available authority to address water issues. Under the CPP umbrella, the Watershed Management Branch of KDOW will provide technical support and leadership with developing and implementing watershed plans to address water quality and quantity problems and threats. Developing watershed plans enables more effective targeting of limited restoration funds and resources, thus improving environmental benefit, protection and recovery.

Watershed plans provide an integrative approach for identifying and describing how, when, who and what actions should be taken in order to meet water quality standards. At this time, a comprehensive watershed restoration plan for the Cane Creek watershed has not been developed. This TMDL provides important pathogen allocations and reductions that will assist with developing a detailed watershed plan to guide watershed restoration. A Watershed Plan for the Cane Creek watershed should address nonpoint sources of pathogen loadings to the watershed and should build on existing efforts as well as evaluate new approaches. A comprehensive Watershed Plan should consider both voluntary and regulatory approaches to meet WQS. Pollutant trading may be a viable management strategy to consider for meeting the TMDL load reduction goals

Because of the specific landscape and location of the Cane Creek pathogen impairments, a Watershed Plan should incorporate watershed restoration and protection mechanisms available under the Kentucky Agriculture Water Quality Act. As stated, the Kentucky Agriculture Water Quality Act (KRS 224.71-100 through 224.71-140) was passed by the 1994 General Assembly. The law focuses on the protection of surface water and groundwater resources from agricultural and silvicultural activities. The Act created the Kentucky Agriculture Water Quality Authority, a 15-member peer group made up of producers and representatives from various agencies and organizations. The Act requires all farms greater than 10 acres in size to adhere to the BMPs specified in the Kentucky Agriculture Water Quality Plan. Specific BMPs have been designated for all operations. All producers in the Cane Creek watershed should have developed and implemented their individual Agriculture Water Quality Plans. State and Federal financial support have been provided to assist producers with implementing the BMPs specified in their Agriculture Water Quality Plans. In addition to agriculture sources, human contribution of pathogens in the watershed must be addressed as well. A Cane Creek watershed plan should include an inventory of septic systems in the watershed, their installation dates and note whether they are likely to be performing adequately, or failing. The plan should further evaluate alternative (non-septic) onsite wastewater treatment systems including decentralized wastewater treatment options to remediate areas with failing systems. The Plan should also incorporate the requirements of Groundwater Protection Plans for management, operation and maintenance of onsite wastewater treatment systems. All straight-pipe discharges of wastewater are illegal and must be eliminated in order to reduce pathogen loading in the watershed.

9.1 Public Participation

This TMDL was published for a 30-day public notice period beginning October 5th, 2007 and ending November 7th, 2007. A notification was sent to all newspapers in the Commonwealth of Kentucky and an advertisement was placed in four newspapers proximal to Powell County; these were the *Wolfe County News*, the *Mt. Sterling Advocate*, the *Irvine Citizen Voice and Times* and the *Beattyville Three Forks Tradition*. Additionally, the press release was distributed electronically through the Nonpoint Source Pollution Control Mailing List (http://www.water.ky.gov/sw/nps/Mailing+List.htm), which is sent to persons interested in water quality issues, as well as the 'Press Release' mailing list maintained by the Governor's Office of media outlets across the Commonwealth.

All comments received during the public notice period have been incorporated into the administrative record for this TMDL. After consideration of each comment received, revisions were made to the TMDL report and responses were prepared and mailed to each agency which commented during the public notice process.

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Appendix A. Modeling Report

1.0 Use of Proportional Area Flow

As stated in Section 7.0, Data Analysis, flow data from the USGS Red River gage at Hazel Green was used to generate the flow data used in this TMDL for the Cane Creek watershed. Below are the correlations between flows taken in the Cane Creek watershed at Station 1 and nearby Red River gages, Hazel Green (03282500) and Clay City (03283500). As stated, the proximity, lack of flow control and high correlation of Hazel Green made it the best choice for comparison to the Cane Creek watershed.

Only final data (USGS reports both final and provisional flow data for its gages) available at the time data analysis was performed were used to generate the duration curves used in this TMDL. The period of record for the Hazel Green gage was from 4/1/54 to 9/30/04, a period which was more than sufficient to smooth out the effects of extreme wet and dry years without the inclusion of the provisional data (which included the data from 10/1/04 forward).

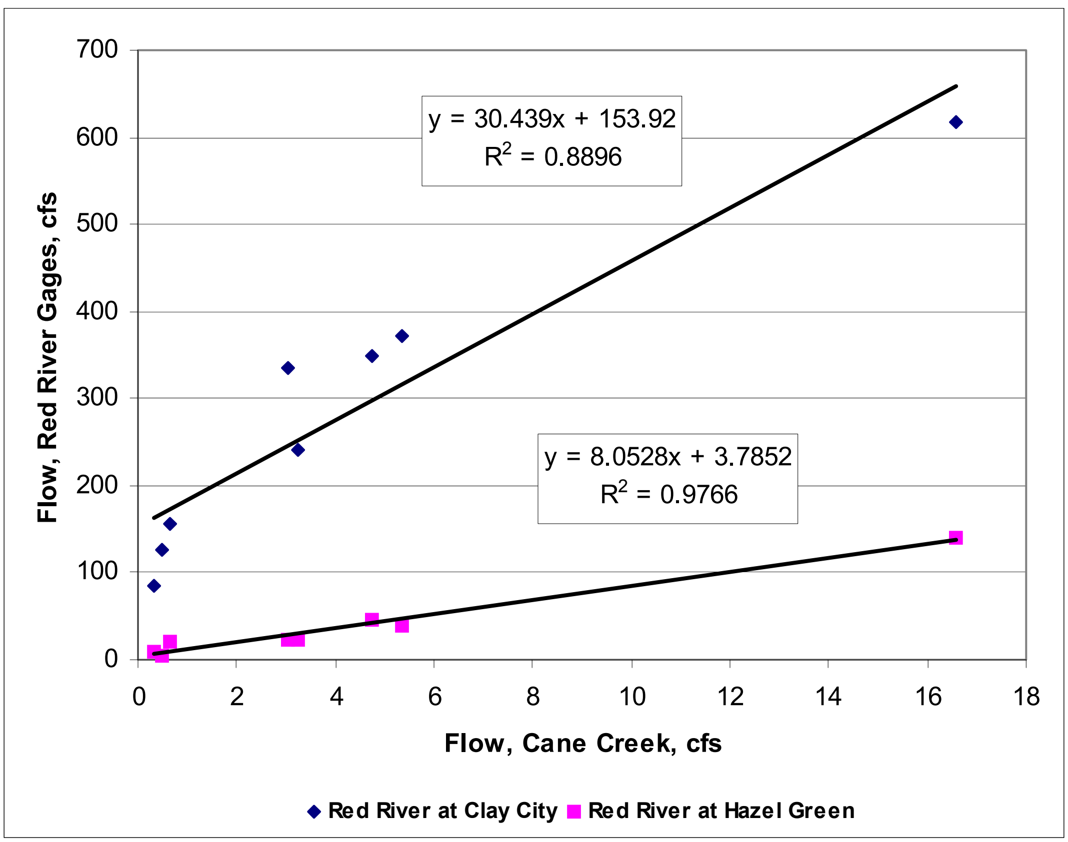

Figure A.1 Correlation Between Flow at Cane Creek and Two Red River USGS Gages

2.0 Stormflow

Sample points are often labeled on Load Duration Curves in a way that illustrates whether a sample was taken during the runoff portion of a storm's hydrograph. This allows further insight into critical conditions: For instance, although the high-flow portion of the duration curve might be the period with the greatest loading from a source, it may also be that samples taken during high-flow conditions subsequent to rain events show more loading than samples taken during high-flow conditions which are not immediately connected with rain events. This information can point to the types of BMPs that would best address the delivery of pollutant loading to the system.

To determine whether a sample is taken during the runoff portion of a storm hydrograph, the percent stormflow was calculated using the Hydrograph Separation (or HYSEP) method developed by USGS (1996). HYSEP includes different mathematical protocols to separate baseflow from stormflow on a given day, and KDOW used the Sliding Interval approach, see USGS (1996) for further discussion. After subtracting baseflow, HYSEP determines the flow on a given day compared to the lowest flow in a 5-day period around that day, and if this change is greater than 50%, the sample taken on that day is considered to be from the runoff portion of a storm's hydrograph.

The Visual Basic routine used to perform Hydrograph Separation requires that there be no missing data (which in this case are daily average flow values reported from the Hazel Green gage) in the period of record. Therefore, provisional data from 10/1/04 forward were added to the final dataset. Further, average flows for some days were missing from the provisional dataset. Missing data were therefore generated by averaging the two data points surrounding the missing period, this was necessary for the period from 4/1/05 through 4/4/05.

On days where a sample was taken which HYSEP determined had a percent stormflow greater than 50%, the absolute flow was also considered before labeling the data point a storm event on Figures 8.1 through 8.5. Specifically, on 9/20/05 at Cane Creek Station 1, the flow generated by proportional area flows was 0.01 cfs. This data point was labeled by HYSEP as having greater than 50% stormflow, but such as small volume does not constitute sufficient runoff to carry a significant amount of pollutant loading to the system by overland flow, and therefore was not labeled as a storm event on Figure 8.5. For this report, a rain event and a change in flow of greater than 0.3 cfs were required in order for sampling point to be labeled as a stormflow event on Figures 8.1 through 8.5. This was based on best professional judgment and review of the field datasheets for that day, which record whether rainfall occurred in the watershed during the 48 hours preceding the sampling event.

The reverse applied as well: On days where HYSEP did not indicate a 50% stormflow but the change in flow within the 5-day window around the sample was greater than 0.3 cfs and the field datasheet indicated rainfall in the 48-hour period immediately before the sample was taken, the data point was labeled as a storm event on the LDC graph. Specifically, the 7/19/05 sampling event had a percent stormflow of 47.4% (relative to other sampling data collected at Station 1), but met the other criteria and was labeled as a runoff event.

3.0 Extreme Low Flows

When building the flow duration curves, the extreme low flows (i.e., the 99% and 100% flows at each station) were plotted approximately to avoid trying to graph the log of zero. This approximation was done in a way that showed any sample near this end of the curve that violated the criterion plotted above the curve, and vice versa for samples that did not violate the criterion. While this approximation has the effect of showing flow when in reality the creek was dry at these stations, the underestimation of zero-flow days was discussed in Section 7.2 above and accounted for quantitatively in the MOS.

4.0 Reporting of Land Use Categories

The land uses generated by the 2001 NLCD were amalgamated for presentation purposes within Section 3.3, specifically in Tables 3.2 and 3.3 of this report. All forested land (deciduous, evergreen and mixed) and shrubbery was aggregated and reported as one category. Further, all residential landuse area was aggregated and reported as one category; the NLCD returned small but positive values for three types of residential landuses—Developed Open Space, Low-Intensity Residential, and High-Intensity Residential. Developed Open Space is a term applied to differing types of landuse, within urban areas it is the designation given to parkland and other green areas. However, in a rural watershed such as Cane Creek, it designates residential areas with insufficient density to be classified as Low-Intensity Residential (James Seay, 2006, Personal Communication).

5.0 Percent Reductions Calculated by LDC Zone at All Stations

Below are the reductions calculated for all LDC zones at all stations except Station 2, if there were exceedances of the WQC available with which to calculate reductions. If no exceedances existed, only the TMDL Target Load (i.e., the final load allocation) was reported for that zone. Note the loads in the tables below were not multiplied by the drainage area ratios found in Table 8.6, while the Final TMDL Table (Table 8.7) was so modified: This difference should be noted when making comparisons between these tables and Table 8.7.

Table A.1 TMDL Data for Station 5

Flow Zone	Existing Conditions		TMDL = WLA + LA + MOS				TMDL Target	Percent Reduction Needed to Achieve TMDL Target	
	Load (billion colonies/day)		TMDL (WQC as a Load) (billion colonies/day)	Final Allocation (billion colonies/day)		MOS (billion colonies/ day)	TMDL Target Load (WQC minus MOS) (billion colonies/day)	Percent Reduction (billion colonies/day)	
	Wasteload	Load		WLA[1]	LA			WLA	LA
High Flows	0	*	122.3	0	110.1	12.2	110.1	0%	*
Moist	0	48.1	9.6	0	8.7	0.96	8.7	0%	82.0%
Mid-Range	0	11.9	4.8	0	4.3	0.48	4.3	0%	64.1%
Dry	0	*	1.2	0	1.1	0.122	1.1	0%	*
Low Flows	0	*	0.127	0	0.11	0.013	0.11	0%	*

* No samples exceeded the WQC in this zone: The percent reduction needed is unknown.

[1]Any future permitted point source must meet permit limits based on the Water Quality Standards in 401 KAR 5:031, and must not cause or contribute to an existing impairment.

Table A.2 TMDL Data for Station 4

Flow Zone	Existing Conditions		TMDL = WLA + LA + MOS				TMDL Target	Percent Reduction Needed to Achieve TMDL Target	
	Load (billion colonies/day)		TMDL (WQC as a Load) (billion colonies/day)	Final Allocation (billion colonies/day)		MOS (billion colonies/day)	TMDL Target Load (WQC minus MOS) (billion colonies/day)	Percent Reduction (billion colonies/day)	
	Wasteload	Load		WLA[1]	LA			WLA	LA
High Flows	0	90.6	38.2	0	34.3	3.8	34.3	0%	62.1%
Moist	0	68.7	9.5	0	8.6	1.0	8.6	0%	87.5%
Mid-Range	0	*	3.3	0	3.0	0.3	3.0	0%	*
Dry	0	*	1.3	0	1.1	0.126	1.1	0%	*
Low Flows	0	*	0.132	0	0.12	0.013	0.12	0%	*

* No samples exceeded the WQC in this zone: The percent reduction needed is unknown.

[1]Any future permitted point source must meet permit limits based on the Water Quality Standards in 401 KAR 5:031, and must not cause or contribute to an existing impairment.

Table A.3 TMDL Data for Station 3

Flow Zone	Existing Conditions		TMDL = WLA + LA + MOS				TMDL Target	Percent Reduction Needed to Achieve TMDL Target	
	Load (billion colonies/day)		TMDL (WQC as a Load) (billion colonies/day)	Final Allocation (billion colonies/day)		MOS (billion colonies/ day)	TMDL Target Load (WQC minus MOS) (billion colonies/day)	Percent Reduction (billion colonies/day)	
	Wasteload	Load		WLA[1]	LA			WLA	LA
High Flows	0	455.3	65.8	0	59.2	6.6	59.2	0%	87.0%
Moist	0	36.1	11.0	0	9.9	1.1	9.9	0%	72.6%
Mid-Range	0	65.1	5.6	0	5.0	0.56	5.0	0%	92.3%
Dry	0	*	2.1	0	1.9	0.209	1.9	0%	*
Low Flows	0	0.1	0.076	0	0.07	0.008	0.07	0%	53.1%

* No samples exceeded the WQC in this zone: The percent reduction needed is unknown.

[1]Any future permitted point source must meet permit limits based on the Water Quality Standards in 401 KAR 5:031, and must not cause or contribute to an existing impairment.

Table A.4 TMDL Data for Station 1

Flow Zone	Existing Conditions		TMDL = WLA + LA + MOS				TMDL Target	Percent Reduction Needed to Achieve TMDL Target	
	Load (billion colonies/day)		TMDL (WQC as a Load) (billion colonies/day)	Final Allocation (billion colonies/day)		MOS (billion colonies/ day)	TMDL Target Load (WQC minus MOS) (billion colonies/day)	Percent Reduction (billion colonies/day)	
	Wasteload	Load		WLA[1]	LA			WLA	LA
High Flows	0	879.9	197.35	0	177.6	19.74	177.6	0%	79.8%
Moist	0	99.39	30.44	0	27.4	3.0	27.4	0%	72.4%
Mid-Range	0	*	14.85	0	13.4	1.5	13.4	0%	*
Dry	0	36.7	3.95	0	3.6	0.4	3.6	0%	90.3%
Low Flows	0	*	0.59	0	0.53	0.06	0.53	0%	*

* No samples exceeded the WQC in this zone: The percent reduction needed is unknown.

[1]Any future permitted point source must meet permit limits based on the Water Quality Standards in 401 KAR 5:031, and must not cause or contribute to an existing impairment.

Table A.6 TMDL Exceedance Summary

Flow Zone	Station 5			Station 4			Station 3			Station 2			Station 1		
	(Upper) Right Fork Cane Creek of Cane Creek			Middle Fork of Right Fork Cane Creek			Lower Cane Creek of Cane Creek			(Lower) Right Fork Cane Creek of Cane Creek			Cane Creek of Red River		
	Samples	Exceedances	Percent	Samples	Exceedances	Percent	Samples	Exceedances	Percent	Samples	Exceedances	Percent	Samples	Exceedances	Percent
High Flows	2	0	0	2	1	50	1	1	100	2	1	50	2	1	50
Moist	5	2	40	5	1	20	5	3	60	5	0	0	4	4	100
Mid-Range	0	0	0	0	0	0	1	1	100	0	0	0	0	0	0
Dry	0	0	0	1	1	100	2	0	0	2	0	0	3	3	100
Low Flows	2	0	0	0	0	0	1	1	100	1	0	0	1	0	0
Total	9	2	22.2	8	3	37.5	10	6	60	10	1	10	10	8	80

Appendix B. Data

Below are the data used to develop the TMDL (note duplicate E. coli values that were not used in TMDL calculations are also reported in parentheses in this table for informational purposes). Procedures for data use in TMDL development are described in further detail below.

Table B.1 Station 5 Sampling Data

(Upper) Right Fork Cane Creek

Station Name	Stream Name	River Mile	Collection Date	Dissolved Oxygen (% Saturation)	Discharge (ft^3/s)	Dissolved Oxygen (mg/l)	E coli (colonies/100 ml)	% Flow Rank	pH	Specific Conductance (µmhos/cm)	Temperature (°C)
5	Right Fork Cane Creek	2.3	5/4/2005		3.72	11.53	11	9.7%	7.56	152.9	10.01
5	Right Fork Cane Creek	2.3	5/10/2005		1.12	10.09	10	27.0%	7.22	187.8	15.52
5	Right Fork Cane Creek	2.3	5/17/2005		0.68	10.03	2	37.8%	7.36	182.1	14.4
5	Right Fork Cane Creek	2.3	5/25/2005		0.66	8.97	10	37.8%	7.28	189.8	14.97
5	Right Fork Cane Creek	2.3	6/16/2005	103	0.18	9.57	2	65.8%	7.4	236.9	19.97
5	Right Fork Cane Creek	2.3	6/21/2005		0.06	8.96	6 (3)	82.2%	7.35	232.9	19.95
5	Right Fork Cane Creek	2.3	7/13/2005	89	1.64	7.96	1200 (387)	20.7%	7.18	216.7	21.16
5	Right Fork Cane Creek	2.3	7/19/2005	101	0.81	8.59	602	33.3%	7.35	231.7	23.26
5	Right Fork Cane Creek	2.3	8/31/2005	86.8	4.63	7.77	160	7.8%	7.71	195.1	20.93

Table B.2 Station 4 Sampling Data

Middle Fork Right Fork Cane Creek

Station Name	Stream Name	River Mile	Collection Date	Dissolved Oxygen (% Saturation)	Discharge (ft^3/s)	Dissolved Oxygen (mg/l)	E coli (colonies/100 ml)	% Flow Rank	pH	Specific Conductance (µmhos/cm)	Temprature (°C)
4	Middle Fork Right Fork Cane Creek	0.1	5/4/2005		3.99	11.49	21	9.3%	7.56	172.3	10.16
4	Middle Fork Right Fork Cane Creek	0.1	5/10/2005		1.21	9.5	39	26.3%	7.18	224.6	16.94
4	Middle Fork Right Fork Cane Creek	0.1	5/17/2005		0.63	9.74	15	39.1%	7.32	210.2	14.63
4	Middle Fork Right Fork Cane Creek	0.1	5/25/2005		0.65	9.2	29	39.1%	7.27	216.3	15.54
4	Middle Fork Right Fork Cane Creek	0.1	6/16/2005	67.8	0.18	6.33	24	66.6%	5.82	278.8	21.27
4	Middle Fork Right Fork Cane Creek	0.1	7/13/2005	91.6	1.62	8.09	1733 (1600)	21.6%	7.13	245.2	21.81
4	Middle Fork Right Fork Cane Creek	0.1	7/19/2005	98.4	1.09	8.94	145	28.7%	7.18	235.1	24.3
4	Middle Fork Right Fork Cane Creek	0.1	8/31/2005	89.5	6.5	8	570	5.9%	7.75	186.5	20.94

Table B.3 Station 3 Sampling Data

Lower Cane Creek

Station Name	Stream Name	River Mile	Collection Date	Dissolved Oxygen (% Saturation)	Discharge (ft^3/s)	Dissolved Oxygen (mg/l)	E coli (colonies/100 ml)	% Flow Rank	pH	Specific Conductance (µmhos/cm)	Temperature (°C)
3	Lower Cane Creek	0.5	5/4/2005	11.4	5.53		122	11.3%	7.54	195	9.65
3	Lower Cane Creek	0.5	5/10/2005		1.78	9.3	866	28.7%	7.12	246	16.64
3	Lower Cane Creek	0.5	5/17/2005		1.03	8.51	146	39.1%	7.19	229.3	14.56
3	Lower Cane Creek	0.5	5/25/2005		1.24		980	36.6%			
3	Lower Cane Creek	0.5	6/16/2005	63.2	0.22	5.64	131	71.5%	7.03	303.8	20.91
3	Lower Cane Creek	0.5	6/21/2005		0.12	4.95	56	80.6%	6.98	290.4	20.58
3	Lower Cane Creek	0.5	7/13/2005	51.2	0.95	4.41	2800 (2420)	40.7%	6.91	325.5	21.78
3	Lower Cane Creek	0.5	7/13/2005				>2400				
3	Lower Cane Creek	0.5	7/19/2005	78.4	1.9	6.66	426	27.0%	7.18	273.4	24.11
3	Lower Cane Creek	0.5	8/31/2005	83.4	11.21	7.38	1660	5.6%	7.73	205.5	21.11
3	Lower Cane Creek	0.5	9/20/2005	38.2	0.013	3.38	461	96.9%	6.94	339.4	21.66

Table B.4 Station 2 Sampling Data
(Lower) Right Fork Cane Creek

Station Name	Stream Name	River Mile	Collection Date	Dissolved Oxygen (% Saturation)	Discharge (ft^3/s)	Dissolved Oxygen (mg/l)	E coli (colonies/100 ml)	% Flow Rank	pH	Specific Conductance (umhos/cm)	Temperature (°C)
2	Right Fork Cane Creek	0.5	5/4/2005		9.81	12.06	59	10.0%	7.72	176.5	8.59
2	Right Fork Cane Creek	0.5	5/10/2005		3.39	10.15	72	25.7%	7.1	207.3	16.03
2	Right Fork Cane Creek	0.5	5/17/2005		2.07	12.92	31	35.5%	9.57	190.8	12.93
2	Right Fork Cane Creek	0.5	5/25/2005		1.87	9.22	126	37.8%	7.18	202.2	14.45
2	Right Fork Cane Creek	0.5	6/16/2005	88.3	0.51	8.08	29	65.3%	7.33	250.9	19.71
2	Right Fork Cane Creek	0.5	6/21/2005		0.16	8.45	88	83.1%	7.25	229.7	18.93
2	Right Fork Cane Creek	0.5	7/13/2005	85	2.42	8.09	115 (110)	32.4%	7.16	248.5	20.91
2	Right Fork Cane Creek	0.5	7/19/2005	87.1	2.77	7.4	144	29.6%	7.28	241.8	23.16
2	Right Fork Cane Creek	0.5	8/31/2005	87.3	16.49	7.75	770 (720)	6.1%	7.81	202.1	21.1
2	Right Fork Cane Creek	0.5	9/20/2005	72.9	0.065	6.71	11	91.0%	7.25	270.2	19.7

Table B.5 Station 1 Sampling Data

Cane Creek

Station Name	Stream Name	River Mile	Collection Date	Dissolved Oxygen (% Saturation)	Discharge (ft^3/s)	Dissolved Oxygen (mg/l)	E coli (colonies/100 ml)	% Flow Rank	pH	Specific Conductance (umhos/cm)	Temperature (°C)
1	Cane Creek	2.4	5/4/2005		16.59	11.31	101 (99)	28.7%	7.82	176.6	8.58
1	Cane Creek	2.4	5/10/2005		4.75	9.54	461	37.8%	7.29	235.8	17.28
1	Cane Creek	2.4	5/17/2005		3.06	9.83	260	34.6%	7.19	213.9	13.58
1	Cane Creek	2.4	5/25/2005		3.66	9.54	687 (548)	10.0%	7.24	227.9	15.04
1	Cane Creek	2.4	6/16/2005		0.63	7.55	816	68.7%	7.45	235.2	20.99
1	Cane Creek	2.4	6/21/2005		0.32	8.46	816	80.6%	7.52	255.7	19.7
1	Cane Creek	2.4	7/13/2005	74.7	0.48	6.56	3600	74.9%	7.27	273.7	21.87
1	Cane Creek	2.4	7/13/2005				>2400	26.3%			
1	Cane Creek	2.4	7/19/2005	86.5	5.37	7.33	880	5.0%	7.38	254.9	23.88
1	Cane Creek	2.4	8/31/2005	84.7	33.61	7.52	1070	98.1%	7.74	238.4	21.34
1	Cane Creek	2.4	9/20/2005	49.9	0.012	4.56	186	28.7%	7.06	304.3	20.07

B.1 Data Use for TMDL Development

B.1.1. Blank Cells. Blank cells in the tables above mean that particular datum was not collected during that sampling event. For instance, some of the field multi-parameter probes used by KDOW measure dissolved oxygen percent saturation, while some do not, therefore collection of this parameter was sporadic. However, parameters such as dissolved oxygen, pH and temperature are unresponsive to pathogens; the data are reported for informational purposes only.

B.1.2. Dilutions. Data flagged with a greater than symbol (">") represents the lowest dilution analyzed of a sample, and these data were not used for TMDL development (i.e., on 7/13/05 at Site 1, 3600 E. coli colonies/100ml was used instead of the >2400 value).

B.1.3. Duplicate Samples. As stated, duplicate values were not averaged. The higher of the two samples was reported and used to develop the TMDL, see Section 8.2.5, MOS. Duplicate values are reported in the table in parentheses on the day they were taken.

B.2 Fecal Coliform Data

Below is a table of fecal coliform data that prompted the listing of Cane Creek on the 2002 303(d). These data were not used to develop the TMDL as they could not be correlated to the E. coli data collected in 2005.

Table B.6. Fecal Coliform Data, Station KRW011

Station ID	Station Location Name	County	Latitude	Longitude	Date	Parameter	Result (colonies/100ml)
KRW011	CANE CREEK NEAR BOWEN	Powell	37.85175	83.782139	5/27/1998	FECAL COLIFORM	1000
KRW011	CANE CREEK NEAR BOWEN	Powell	37.85175	83.782139	6/11/1998	FECAL COLIFORM	1500
KRW011	CANE CREEK NEAR BOWEN	Powell	37.85175	83.782139	7/14/1998	FECAL COLIFORM	600
KRW011	CANE CREEK NEAR BOWEN	Powell	37.85175	83.782139	8/13/1998	FECAL COLIFORM	250
KRW011	CANE CREEK NEAR BOWEN	Powell	37.85175	83.782139	9/22/1998	FECAL COLIFORM	30
KRW011	CANE CREEK NEAR BOWEN	Powell	37.85175	83.782139	10/27/1998	FECAL COLIFORM	10

Appendix C. Watershed Road Map

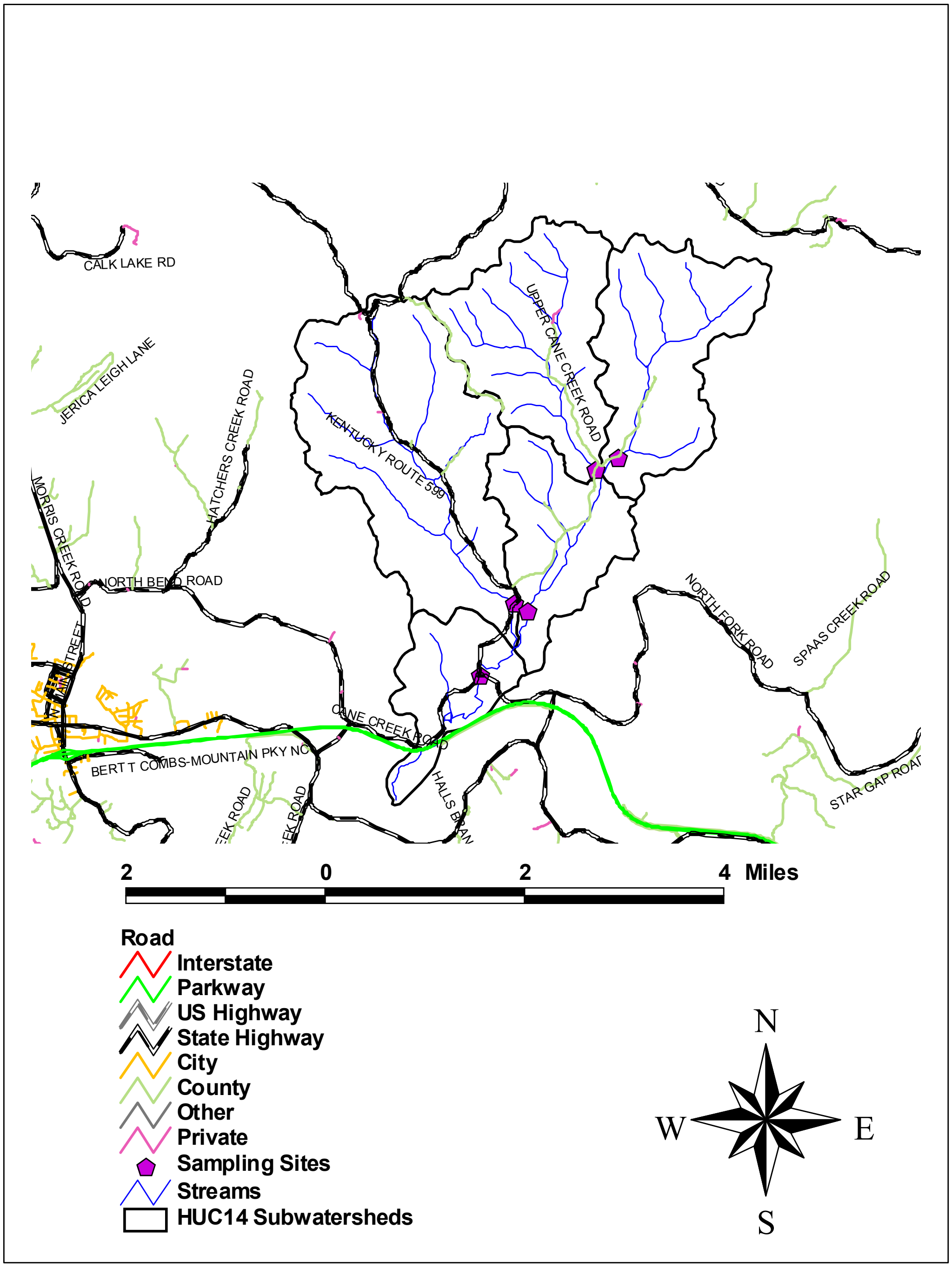

Figure C.1 Watershed Road Map